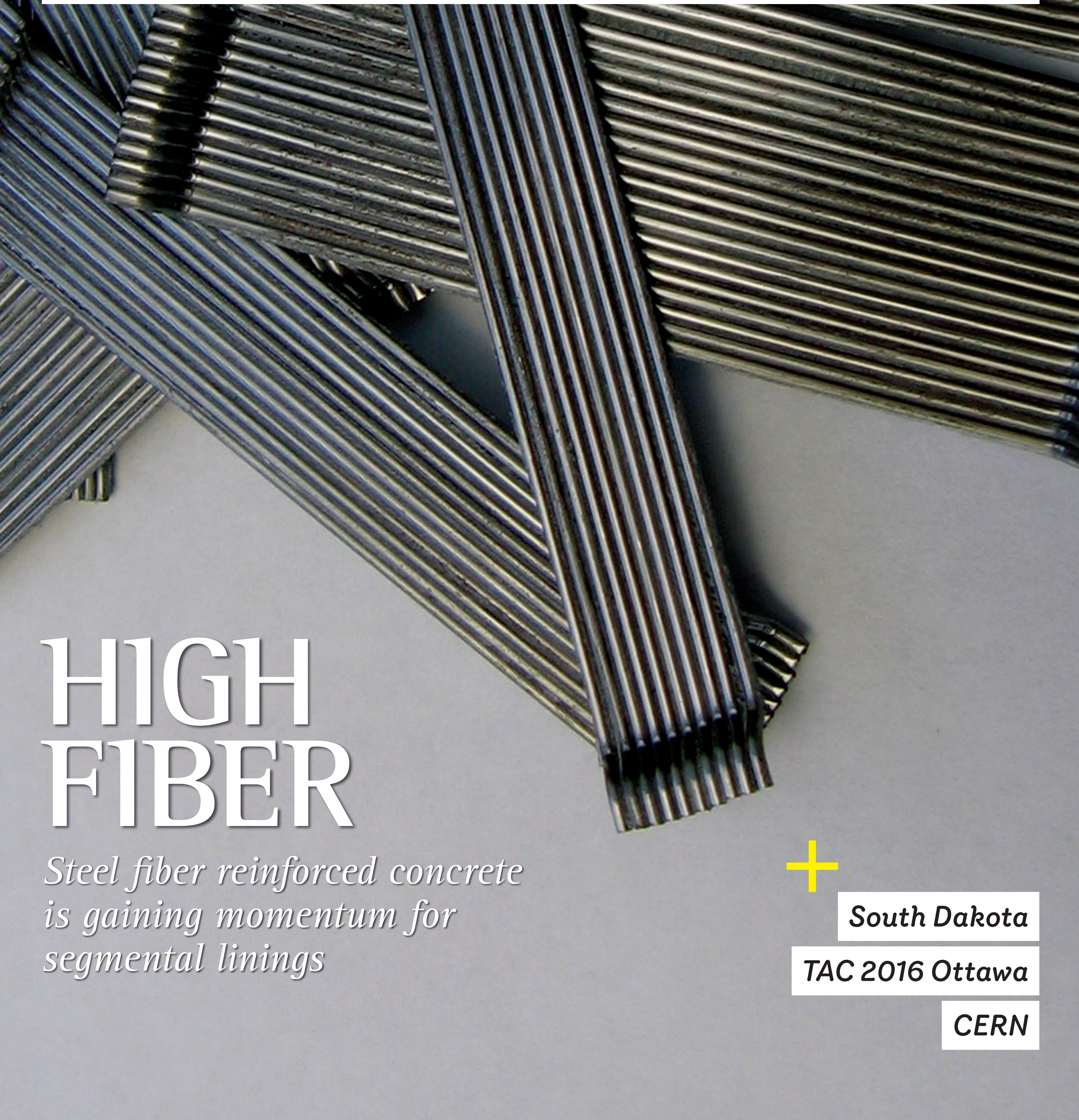
The official publication of the Tunnelling Association of Canada

NORTH AMERICAN EDITION
August ~ September 2016

# Tunnels AND TUNNELLING



## HIGH FIBER

*Steel fiber reinforced concrete is gaining momentum for segmental linings*

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South Dakota

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# COSMIC DEPTH

Excavation and construction for a science lab one mile underground is the first step in better understanding neutrinos, one of the unexplained mysteries of the universe. **Nicole Robinson** reports on the Long-Baseline Neutrino Facility

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OUR UNIVERSE IS permeated with neutrinos—nearly massless particles that interact so rarely with other matter that trillions of them pass through our bodies each second without leaving a trace. Scientists have observed three types of them, and that they can change between these three "flavours," as they say, over longer distances. Based in Batavia, Illinois, a particle physics laboratory called Fermilab undertakes neutrino research, including experiments that beam the particles from a large accelerator complex to a variety of targets.

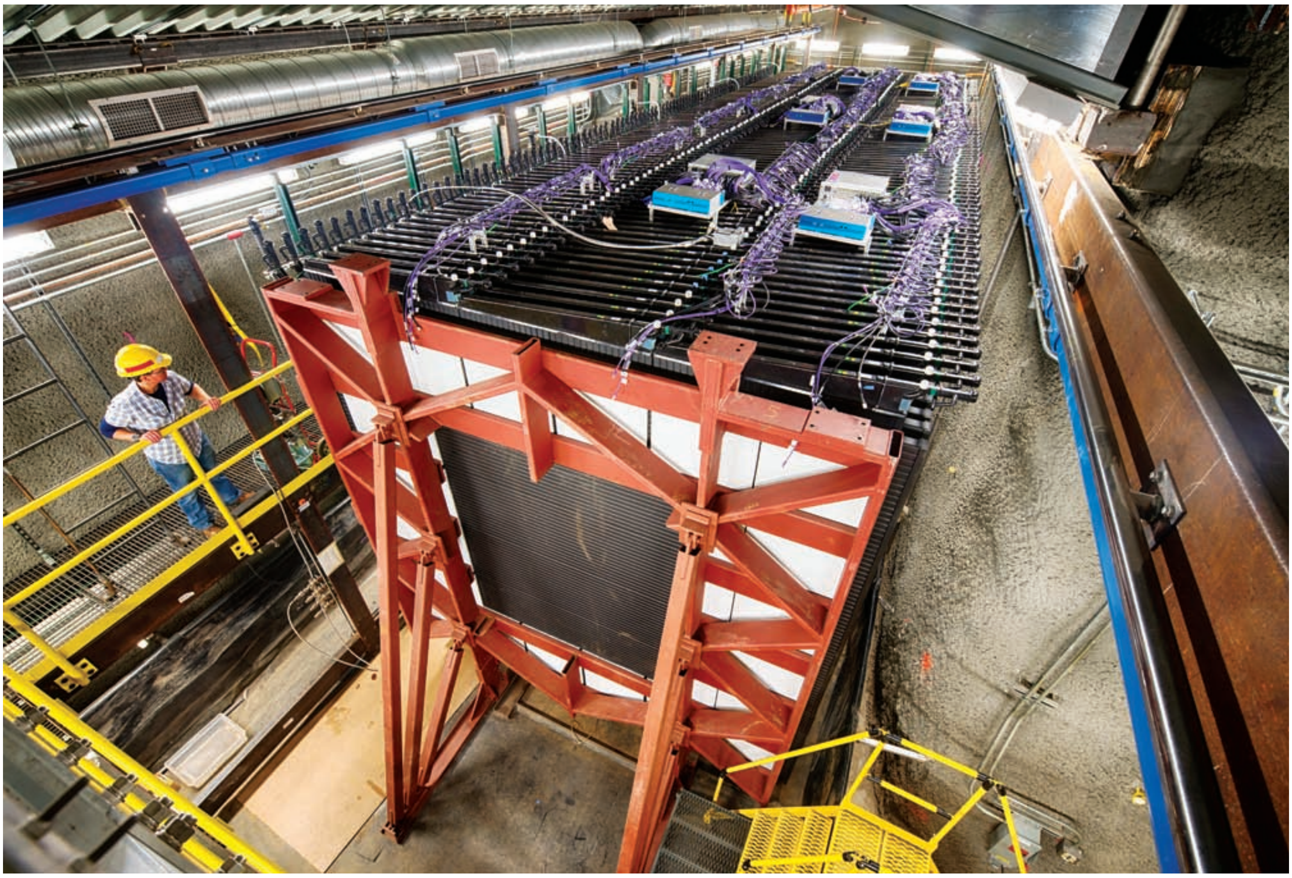
Currently Fermilab has on-going neutrino-based experiments with a detector located 450 miles (724km) away in northern Minnesota at the Soudan Underground Mine State Park.

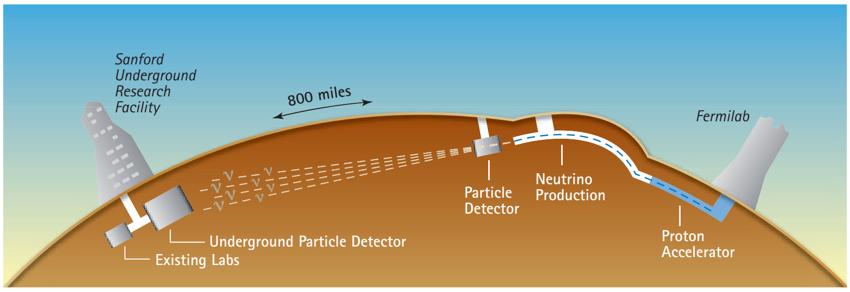
"The distance between Fermilab and Soudan is not quite as advantageous for the science as being a little bit further away, as these neutrinos oscillate and their characteristics change over time and space," explains Tracy Lundin, Fermilab's LBNF conventional facilities project manager.

An RFP released in late June focuses on building a new underground facility at a former gold mine in Lead, South Dakota, about 800 miles (1,290km) away, which Fermilab says is a perfect distance to catch this phenomenon happening—and to try to find out how and why it is happening. The project, the Long-Baseline Neutrino Facility (LBNF), concerns the underground excavation of approximately 350,000 bank cubic yards (267,000 cubic meters) and will be constructed one mile underground.

Once completed, the particle accelerator in Illinois will beam neutrinos straight through the earth to four detectors in the new South Dakota facility. Fermilab says the project has

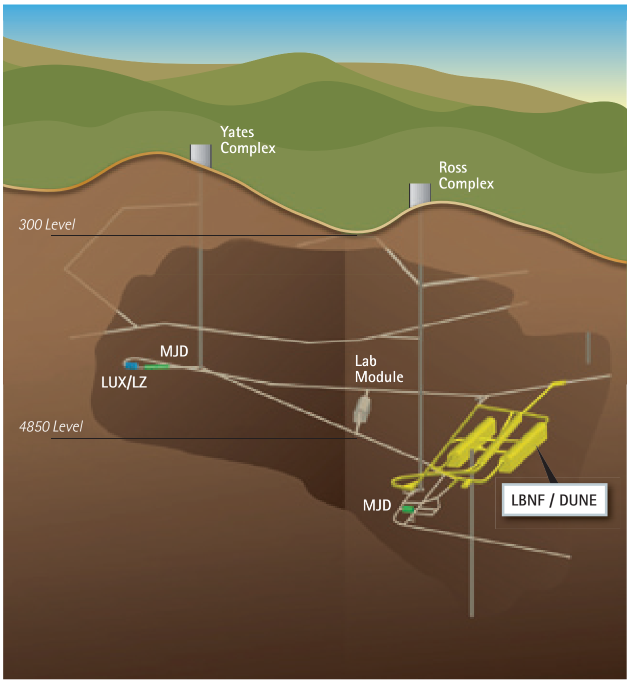
***Below:** The 300t neutrino detector sits 350ft underground at Fermilab and measures the properties of the neutrino beam as it starts its 500-mile journey to the far detector in Minnesota*






container, containing liquid argon at very cold temperatures," Lundin explains. "The detector itself is within that liquid argon bath."

The third cavern is located between these two, and functions like a mechanical space. It has dimensions of about 625ft long by 65ft wide and 40ft tall (190.5m by 19.8m by 12.2m). There is also a series of connecting




been getting a lot of support and gaining momentum. A pre-proposal conference is set for July 19-20 at the former mine, with a tour of the existing underground space.

## GOLD MINE

The LBNF program describes Fermilab in Illinois as the "near site," and the "far site" is the former Homestake gold mine in South Dakota. The mine has been converted to what is now the Sanford Underground Research Facility, whose sole purpose is housing spaces for research primarily driven by very small, subatomic particles coming from cosmic sources. With depths as great as 8,000ft (2.4km), the former mine provides shielding to block out other subatomic particles that get in the way of the research.

Fermilab is bidding the project through a Construction Manager/General Contractor approach (CM/GC), listed with a construction magnitude of USD 250M to USD 350M. Chris Mossey, Fermilab's deputy director for LBNF, explains some of the early work that must be done to support the project's timeline. LBNF will be housed on what the Sanford Underground Research Facility calls the 4850 level, named for its depth in feet (1,478m).

"We started this year executing some reliability projects for the laboratory infrastructure, particularly the shaft we will be using because it's the main access to the 4850 level," Mossey says. The shaft will be renovated, among other work.

"We hope to transition to the pre-excavation work, which is building systems that will support the excavation—such as rock handling systems—in 2017, then switch to production excavation in 2018.

"Virtually all that work will be done through this CM/GC contract and we're very excited it's out on the street."

The plans entail excavation of three separate caverns, each parallel to one another. Two caverns will have nominal dimensions of 500ft long, about 95ft tall and 65ft wide (152.4m by 29m by 19.8m). Each of those two caverns will house two detectors.

"These detectors themselves are immense, self-supporting steel structures that are essentially a slightly pressurized

***Top:* A beam of neutrinos will travel through the earth**

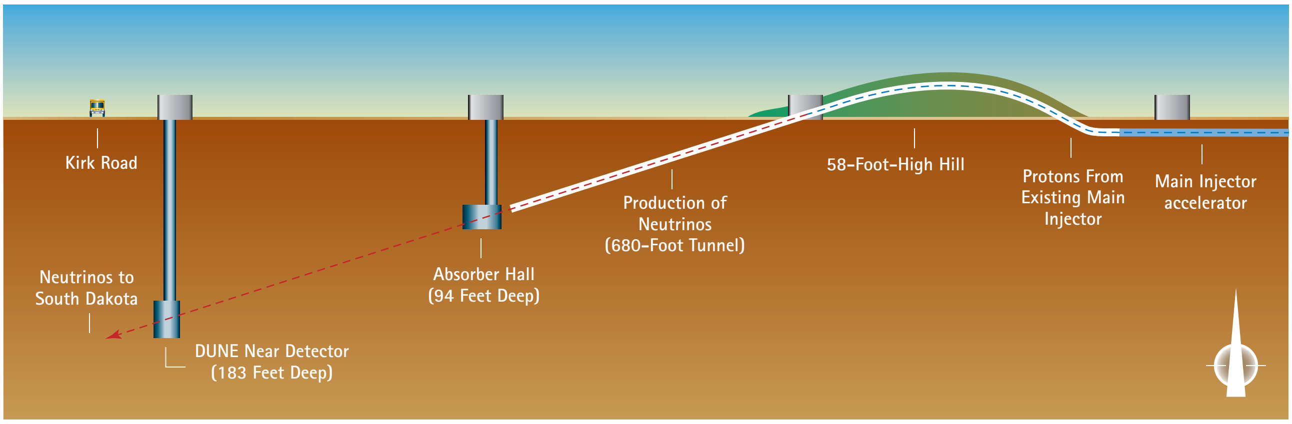
***Right:* Proposed LBNF in yellow**

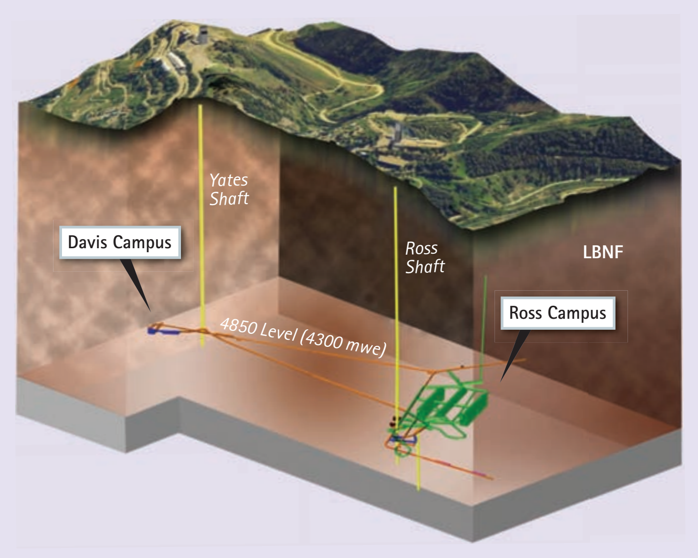
***Below:* Scientists plan to use a 680ft long tunnel at the Fermilab site**

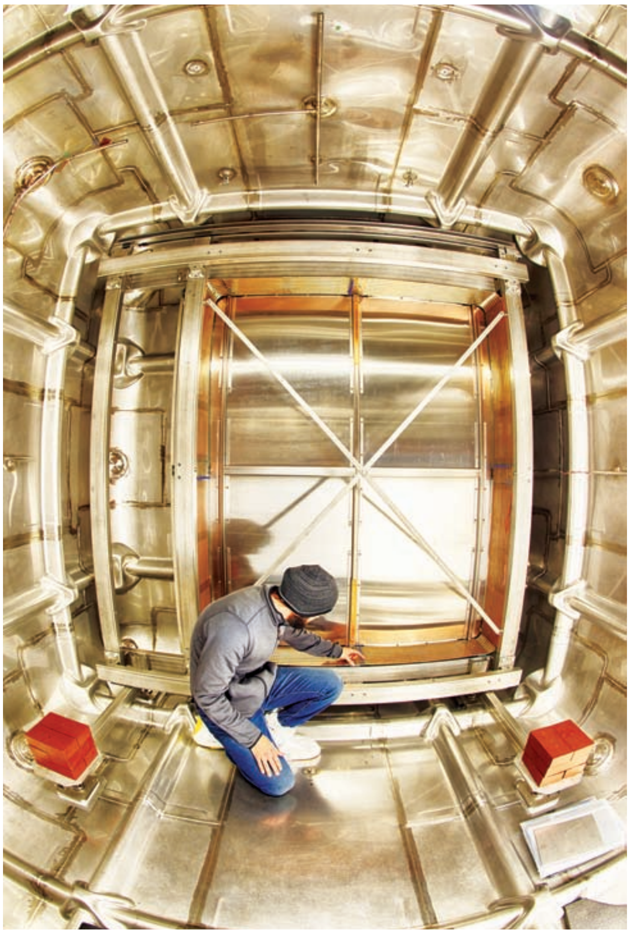
tunnels that tie the caverns together and into existing facilities at the Sanford Underground Research Facility.

"You can imagine a seam containing the gold, diving at a pretty steep dip, and so over the years, they'd go down vertically, and then fan out horizontally, following the seam...They've got old workings that go down, deeper than the 7400 level," Lundin says.

The existing network of hundreds of miles of horizontal drifts has been advantageous for the project team as it worked on the design.





## IDEAL LOCATION

The primary appeal of this former mine site is the depth, which provides the shielding cover, which enables the science. However, the geology has many characteristics that are beneficial for the project.

Almost everything will be built in the Poorman formation, which Lundin describes as a schist with some phyllites and dykes throughout, but not highly prominent. "It's very massive," he says. "In the roughly 2,500ft [762m] of horizontal borings that we've done we had rock quality designations values that were excellent (greater than 90 per cent) for all but about 25ft [7.6m] of the cores. And the fact that we've got miles and miles of existing drifts very close to us, both horizontally as well as vertically—we feel like we have a really, really good handle on the geology."

As well, these miles and miles of existing drifts above and below the project intercept any groundwater infiltration or naturally occurring groundwater. "In walking the 2-3km of existing drifts at the 4850 level, if you look hard you might see two or three seeps," he says. "But you see no active dripping, nor any groundwater. It's just not there."

Mossey adds, "we were looking for a facility that had the shielding quality, and that was the right distance from Fermilab outside of Chicago for the science requirements. We're very fortunate that Sanford lab is on that arc, and then it has all these geological characteristics as well."

## EXPERIMENTATION

Sanford Underground Research Facility is home to a number of existing science experiments, some of which are currently operating on the 4850 level. For example there's the Davis campus, named for Nobel Prize winner Ray Davis who in 1965 began building an experiment in this very mine with the goal of counting neutrinos. It's near one of the two main vertical access shafts, Yates.

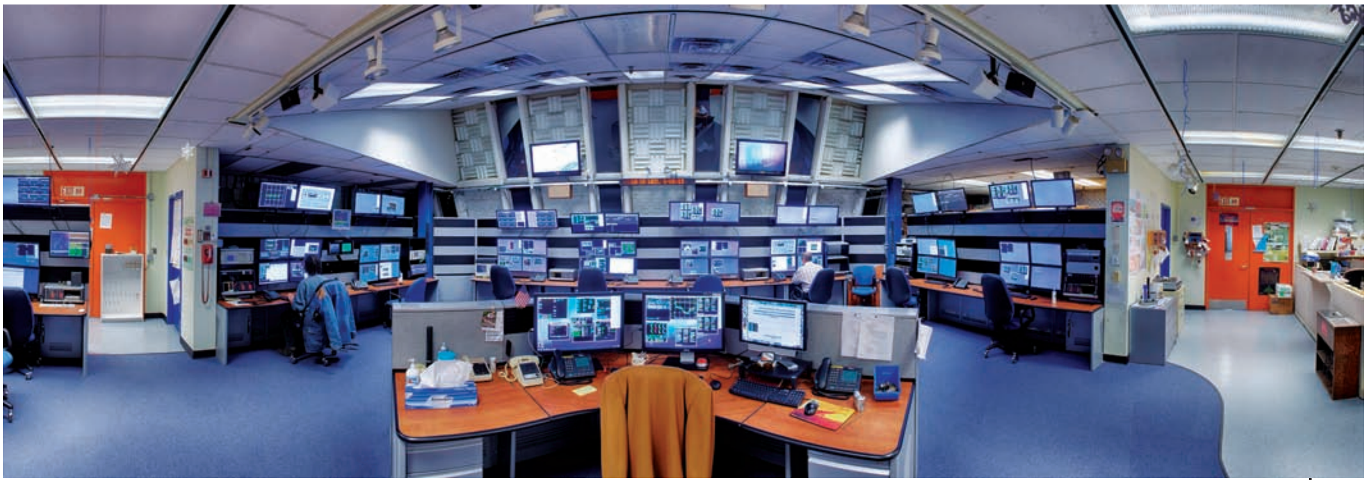
The other shaft, about 1km away, is Ross. Nearby on the Ross campus, researchers began installing a new accelerator last fall for the Compact Accelerator System for Performing Astrophysical Research (Caspar). "This is the most sensitive piece of equipment in the entire Caspar setup," said Frank Strieder, associate professor of physics at the South Dakota School of Mines and Technology.

Among other research in this area of the 4850 level, is the Majorana Demonstrator, so sensitive is has an impenetrable

***Above:* Current and future facilities on the 4850 level**

***Right:* Assembly work inside the LBNF prototype**

***Below:* The two-mile main Injector makes the world's most intense high-energy neutrino beam**



shield made up of six layers of various materials designed to block out minute traces of radiation.

Construction for the new LBNF facility will be very close to the base of the Ross shaft, to which the CM/GC will have complete access according to the current plans.

"The most interesting aspect of the project's design is to overcome the logistical issues," says Amirreza Ghasemi, senior tunneling engineer at Arup, the project designer.

That is specifically the logistics of getting people and excavated material from the 4850 level up to the surface. "Using a 5,000ft [1,524m] deep, relatively small shaft as an access point for a project of this scale; bringing in all the heavy equipment needed for the construction, required utilities of the project, and long columns designed for the cryostat from this shaft; while maintaining it for taking out the excavated material," he elaborates.

Another key challenge is preventing disturbances to existing science experiments to the degree possible.

"The impacts to them are going to be, primarily, the dust from what we think is going to be a drill and blast operation," Lundin says, "and also managing the two primary components of the blast events, peak particle velocity and the air blast overpressure."

LBNF is located purposefully near an exhaust path that is enabled by another existing shaft called Oro Hondo, which is the primary ventilation shaft for the entire facility. "We're situated very nicely to be able to deal with effects of blasting gases and dust," Lundin adds.

In preparation for the blast events, the project team conducted an in-depth test blast program this winter to understand how the blast energy moves through both air as well as the massive rock formation.

***Above:* From the main control Room, operators monitor and control the accelerator complex, and make neutrino beams**

***Below:* A 35t-capacity prototype cryostat for LBNF**

"We believe that the air blast overpressures can be managed," he says. "And one of the things that makes that possible, again, is some of these many existing drifts and spaces. So we can control where the air goes. The trickier part is trying to balance the peak particle velocity."

Discussions with the existing science facilities are focused on peak particle velocity of about 2 inches/second (51mm/second).

"Based on work at another deep underground facility in Canada, SNOLAB, we believe that 2in/second, measured at the existing facility, is a careful balance between what the existing science would like versus what the underground excavators would like."

Fermilab expects to receive proposals by the end of August and to award the CM/GC contract before the end of the year. Plans call for final design of the facility to start this fall. The schedule all depends on the funding profile currently under discussion at the Department of Energy, the project sponsor. A ground breaking could be expected in the next 18-24 months.

Arup is the prime consultant responsible for the underground excavation design, and the electrical, mechanical, plumbing, ventilation, and life and safety design.

## NEAR SITE

Priority has been given to developing the facilities at the far site in South Dakota, and on the heels of that will come design and construction in Batavia, Illinois, at Fermilab to support LBNF. The near site will have separate construction contracts, and currently the project team has done conceptual design and some preliminary design